LPP Sources for HVM EUV Lithography

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October 8, 2013

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Field performance of NXE:3100 LPP Sources

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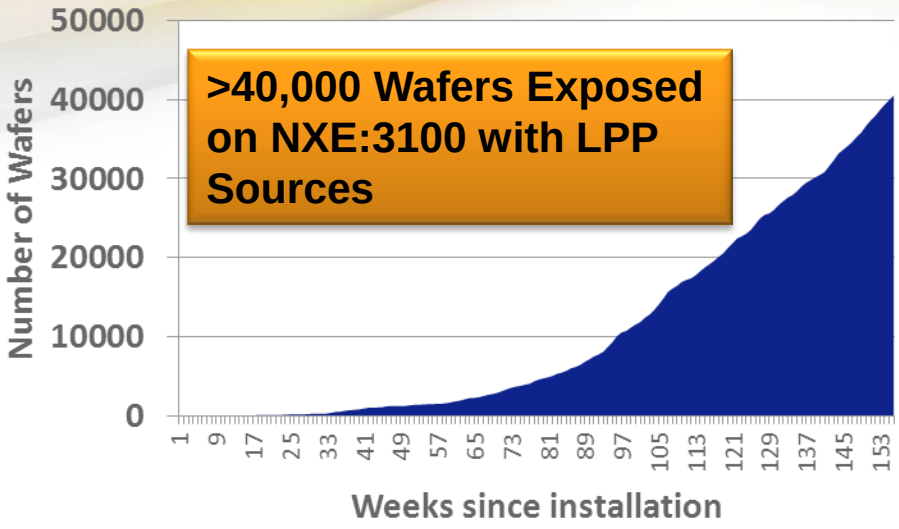
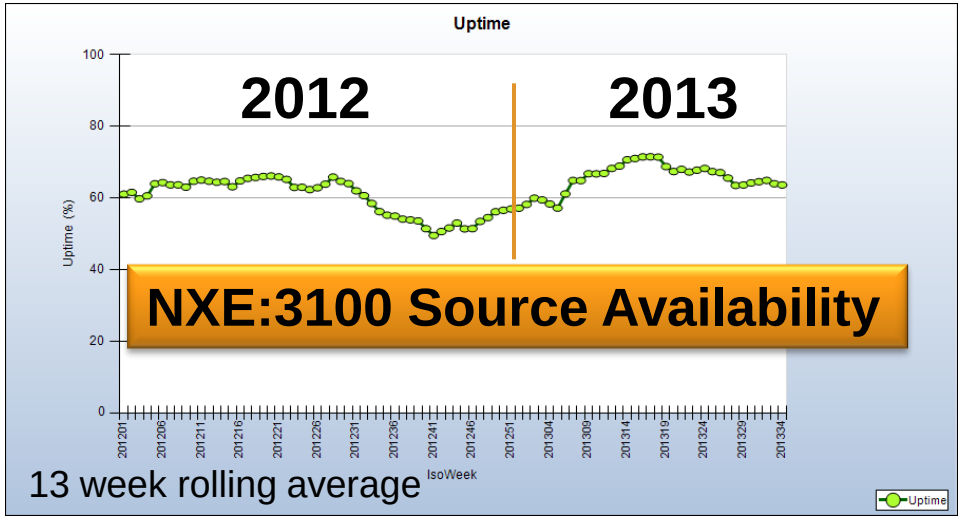
INSTALLED BASE OF NXE:3100 SOURCES

- **Total of 10 NXE:3100 sources are installed and operational**
  - 5 sources installed and exposing wafers at chipmaker development fabs for 2.5 yrs
    - ~100 wafer per day capability
    - <±0.5% dose stability
  - 5 sources in San Diego and Veldhoven for MOPA+PP development, and for technology transfer to NXE:3300B
- **Maintaining up to ~70% source availability in 2013**
  - Average of 5 customer sources
  - Plans in place to improve to 75% by year end

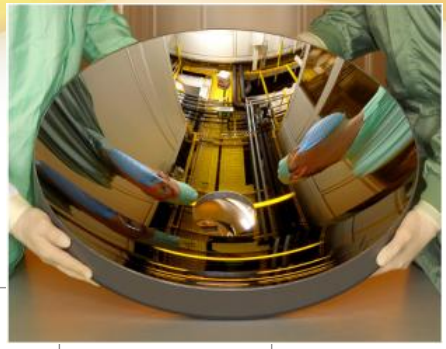


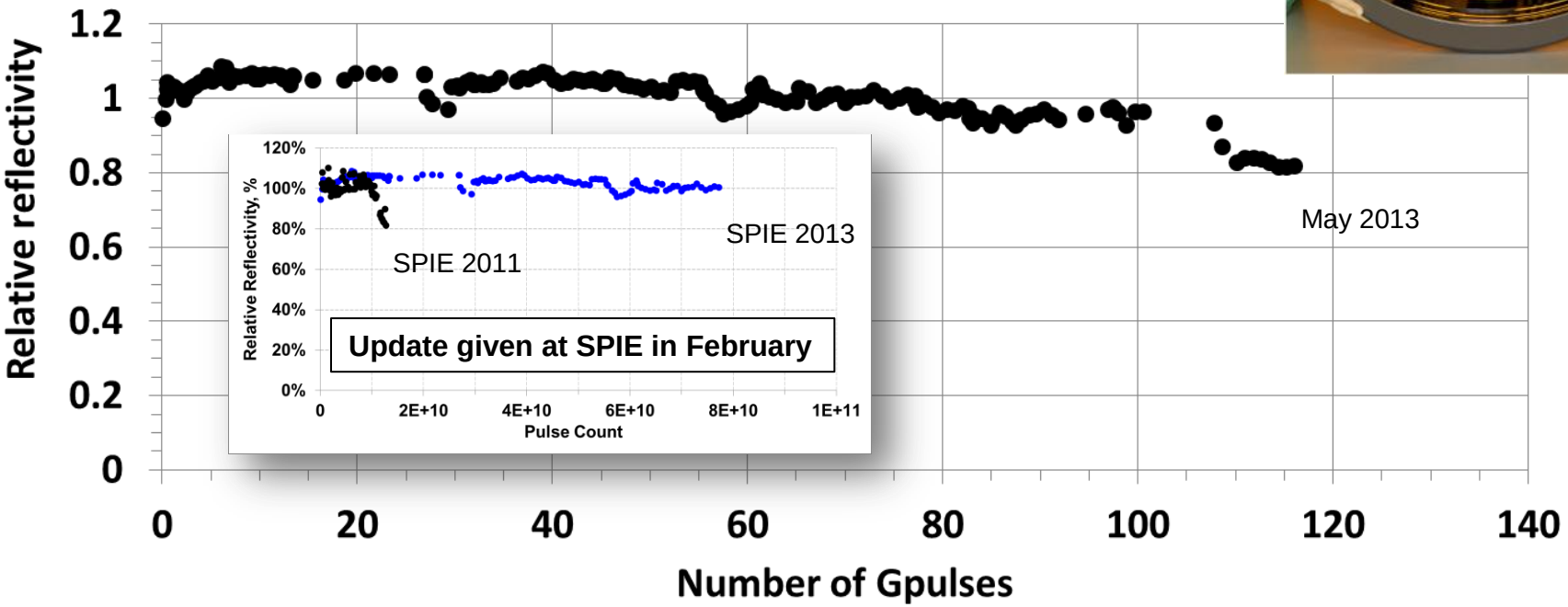


NXE:3100 Collector Lifetime in the Field

Champion lifetime in the field ~11 months (~120 billion pulses)

Six collectors with >6 months lifetime

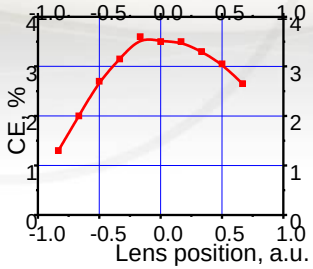


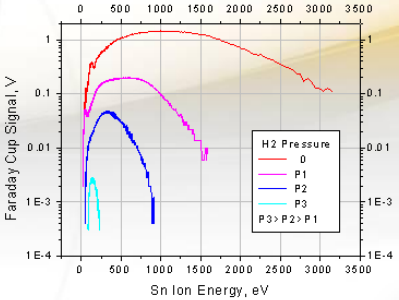


Type	Average Lifetime (sample size)	Best lifetime
Uncapped	7 Gp (8)	15 Gp (1)
Current Cap Layer	**42 Gp (19, 5 still going)**	**120 Gp (1)**

Cap layer development has enabled increased average collector lifetime by >5X since initial installations

Our LPP Source Development History



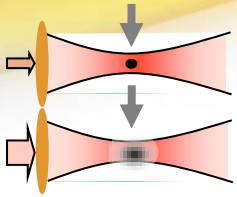


CO_2/Sn for high CE

H_2 debris mitigation

First 5sr collector

MOPA + PP Development



Coatings for collector lifetime

SPF collector

Cymer/ASML cooperation established

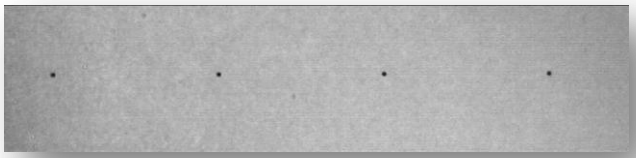
40W stable MOPA+PP

Automated 50W MOPA+PP

2006 2007 2008 2009 2010 2011 2012 2013

NOMO Development

30μm droplets with wide spacing



Proto source integrated with scanner

NXE:3100 source shipment

CO_2 PP

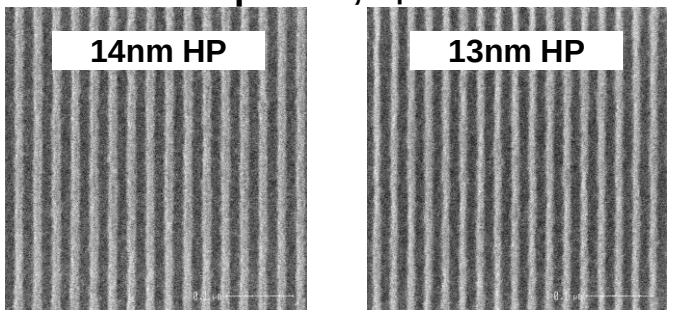
Collector protection to 60W

NXE:3300B Vessel shipment

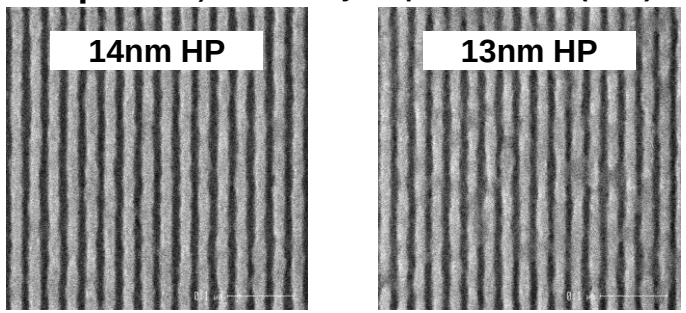
NXE:3300B Resolution for Dense L/S and CH

Single exposure structures with LPP Source

Dipole45, Inpria Resist

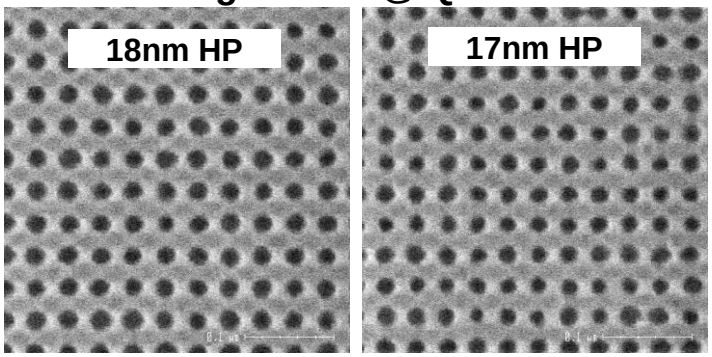


Dipole30, Chemically Amplified Resist (CAR)

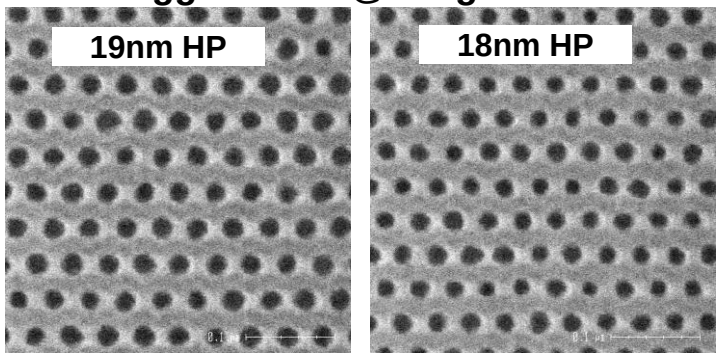


13nm HP with single exposure on NXE:3300B

Regular CH @ Quasar 30



Staggered CH @ Large Annular



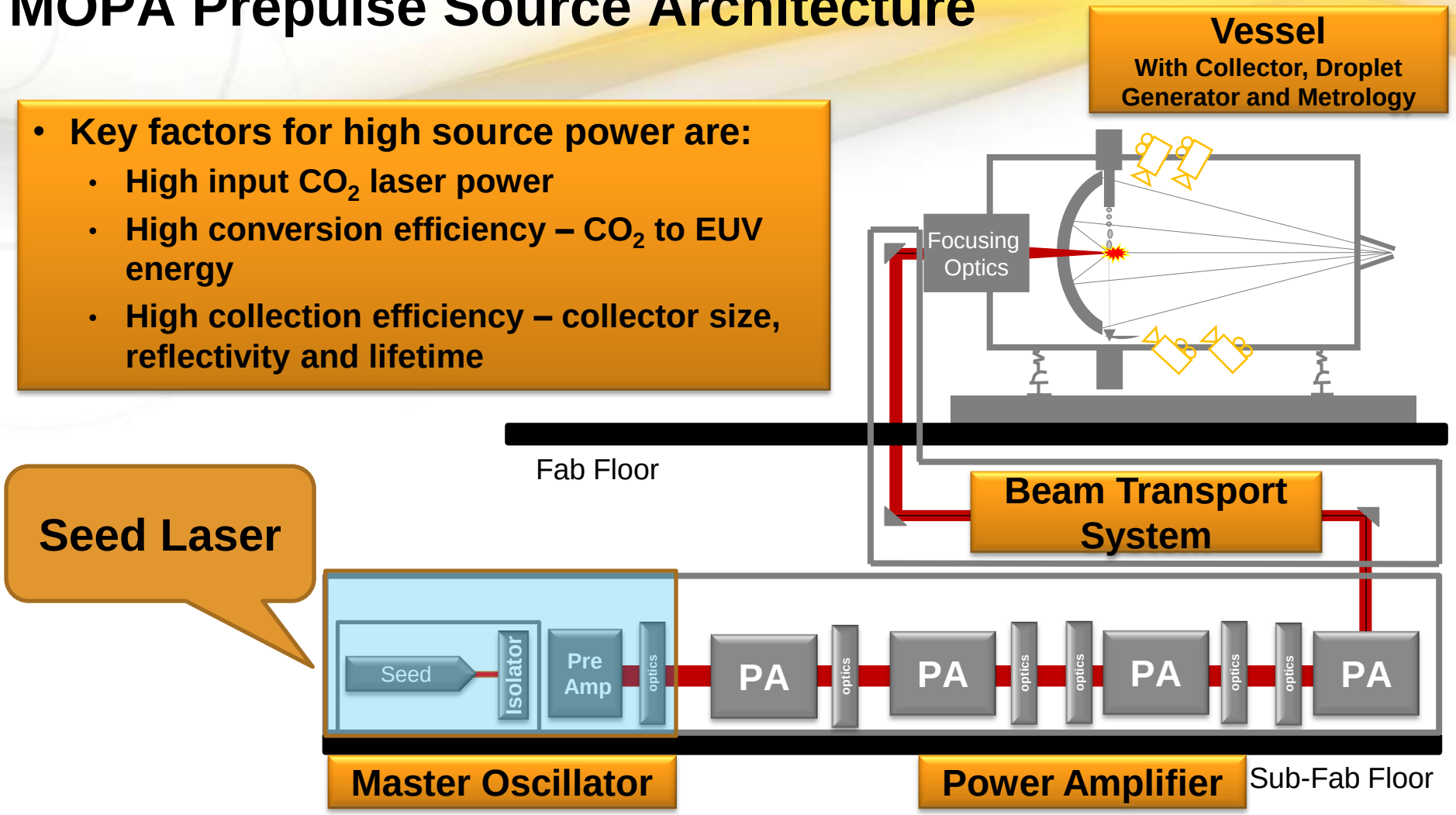
Dense CH imaging achieved down to 17nm HP on NXE:3300B

Second Generation EUV Sources for NXE:3300B

CYMER

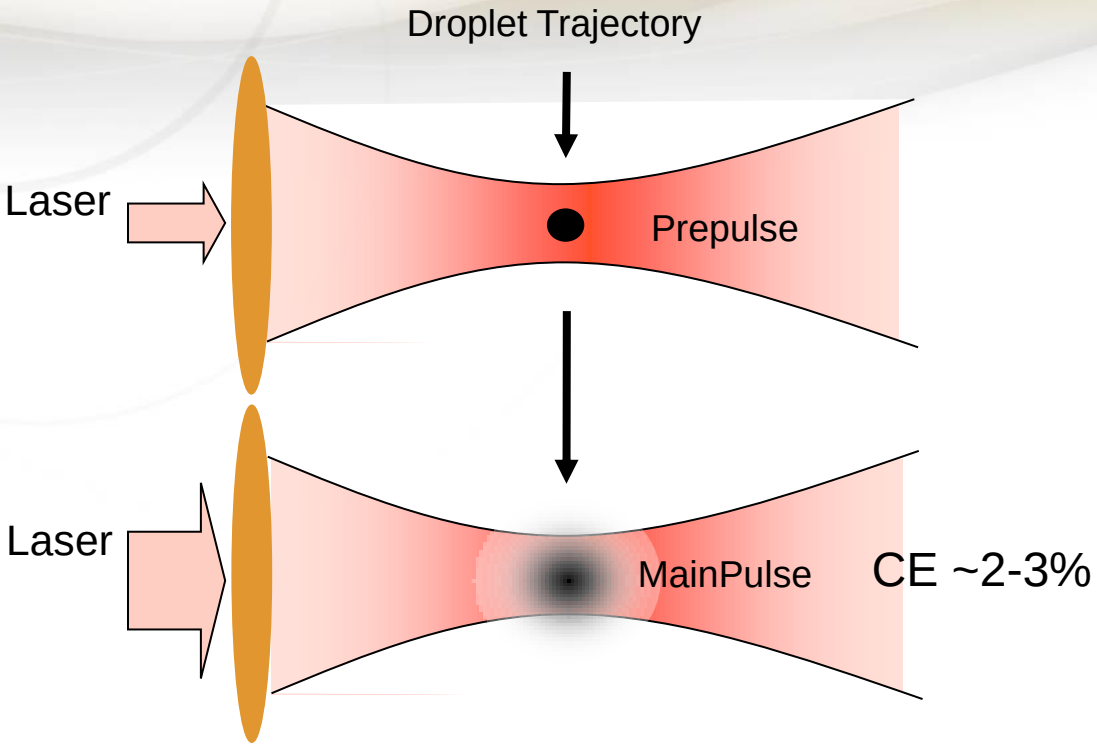
MOPA Prepulse Source Architecture

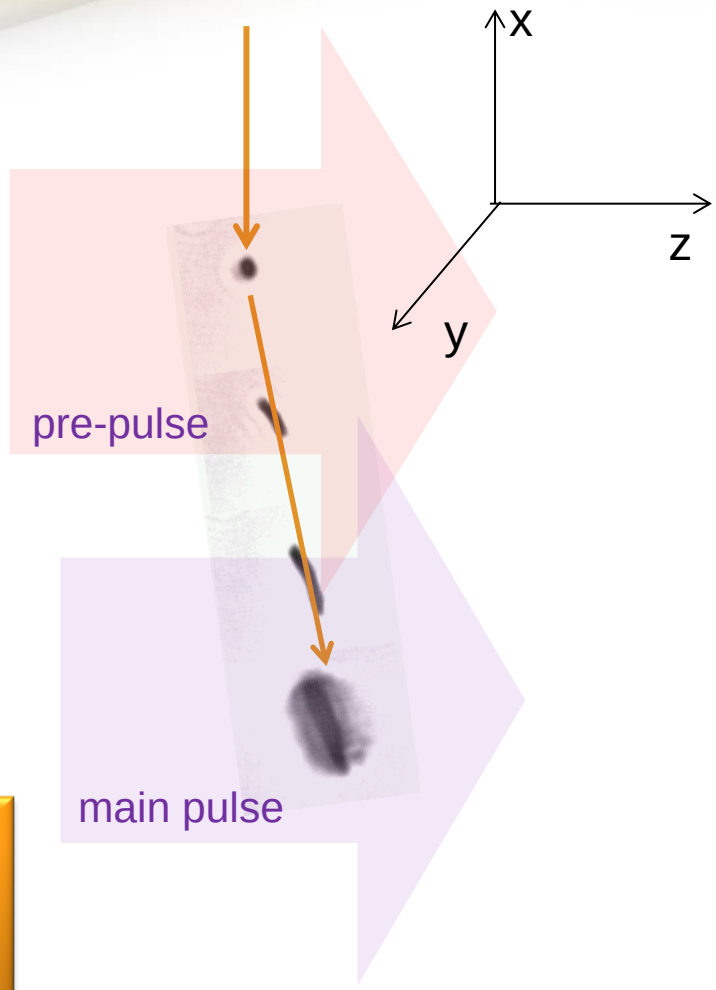
- **Key factors for high source power are:**
  - **High input CO_2 laser power**
  - **High conversion efficiency – CO_2 to EUV energy**
  - **High collection efficiency – collector size, reflectivity and lifetime**



MOPA - Master Oscillator Power Amplifier

Pre-pulse – Key To Scaling EUV Power

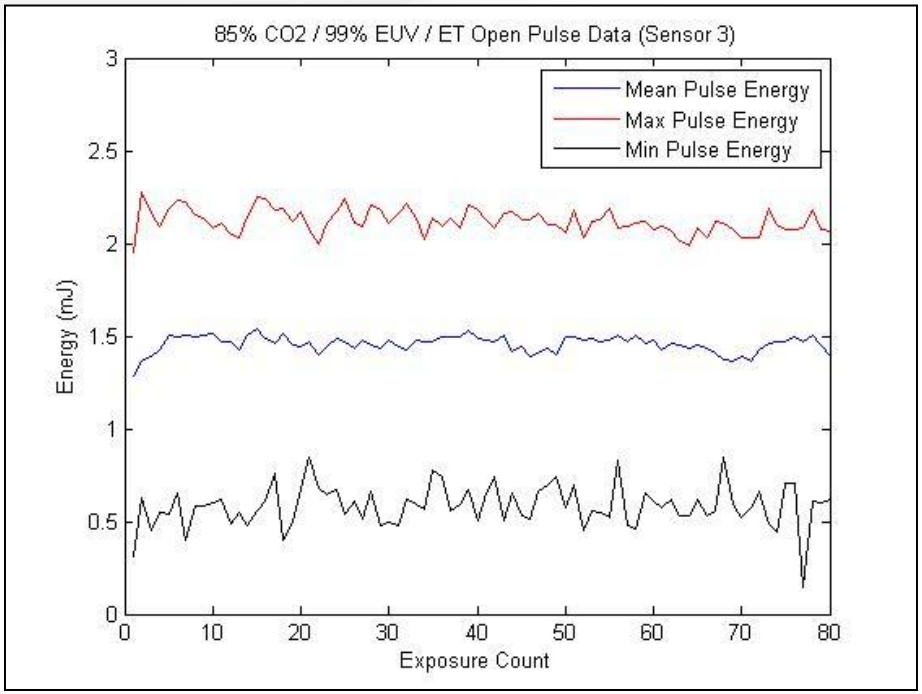




- Target conditioning provides better overlap of the CO_2 main pulse beam with the target material

NXE:3300B Source Qualification Progress in MOPA Prepulse: 60W Open Loop Power

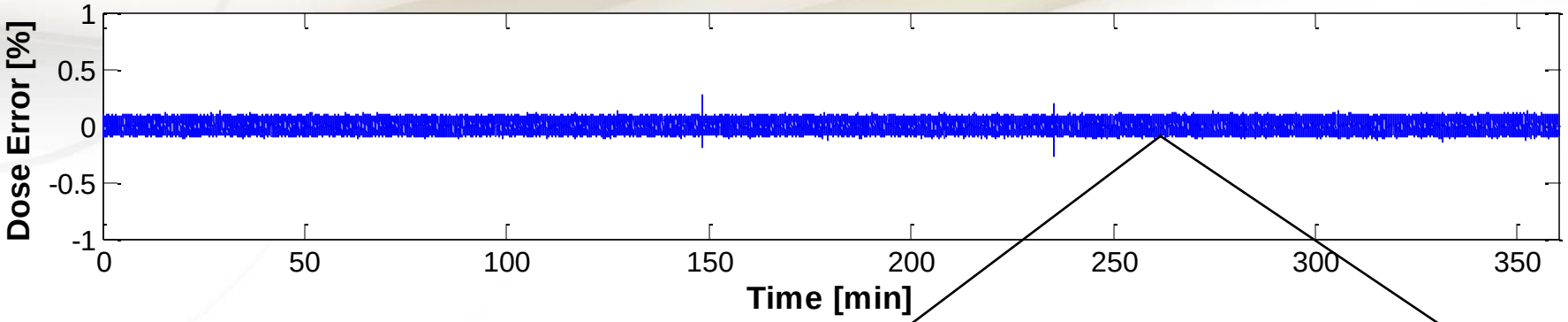
60W (open loop)

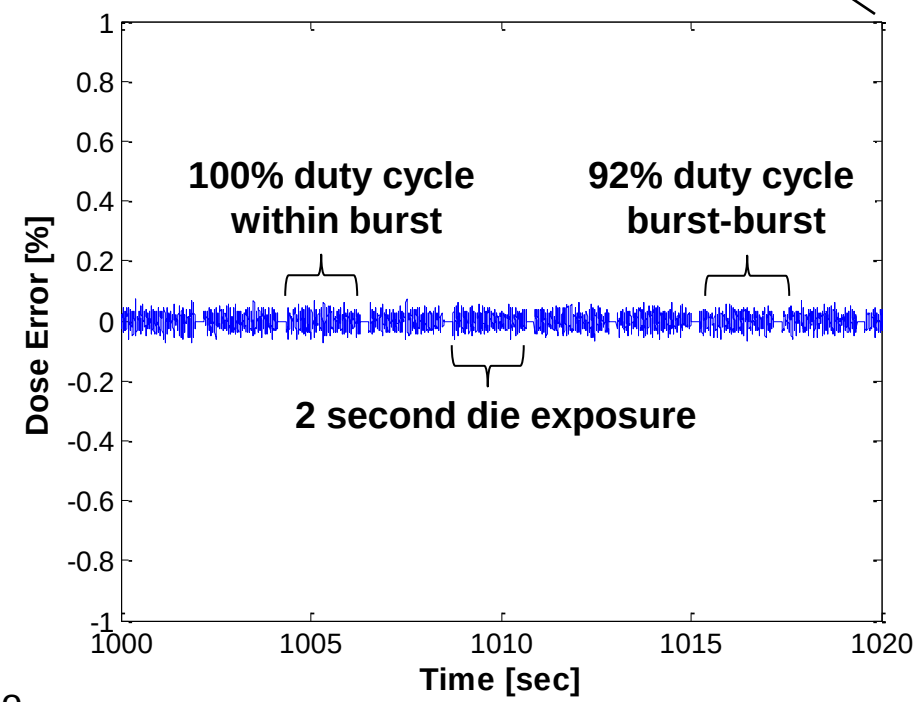


- **50kHz repetition rate**
- **Initial dose control results shown, dose margin will be improved after full controls are applied**

MOPA Prepulse Performance at 40W

Exceptional Dose Stability <±0.5%





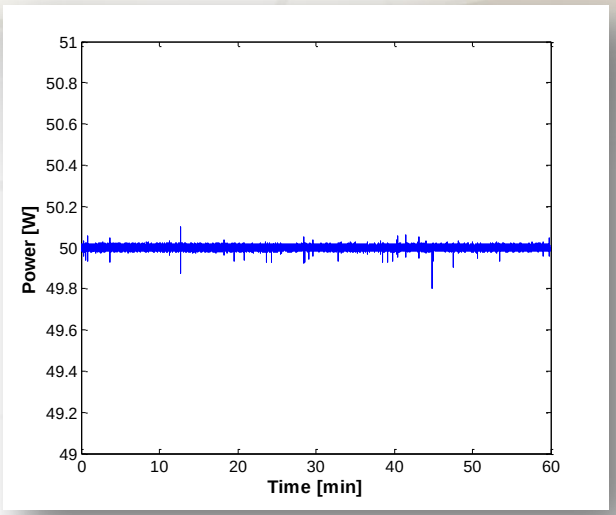
Operating Conditions

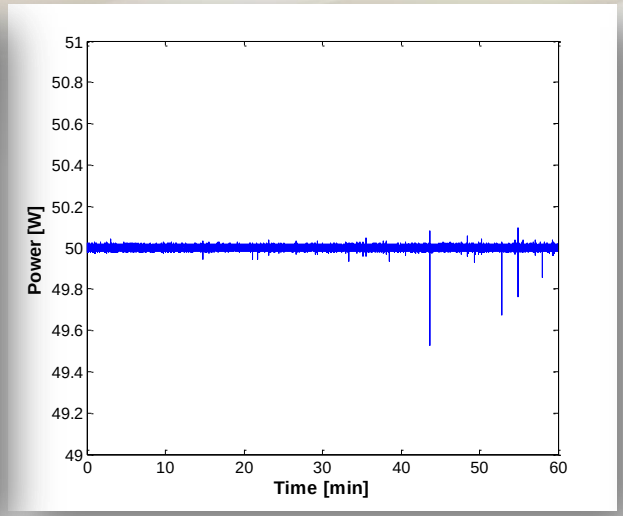
- Prepulse
- 50kHz Rep Rate
- 2 second die exposures
- 100% duty cycle within the burst, 92% burst to burst
- Closed loop control in x, y, z, E and t

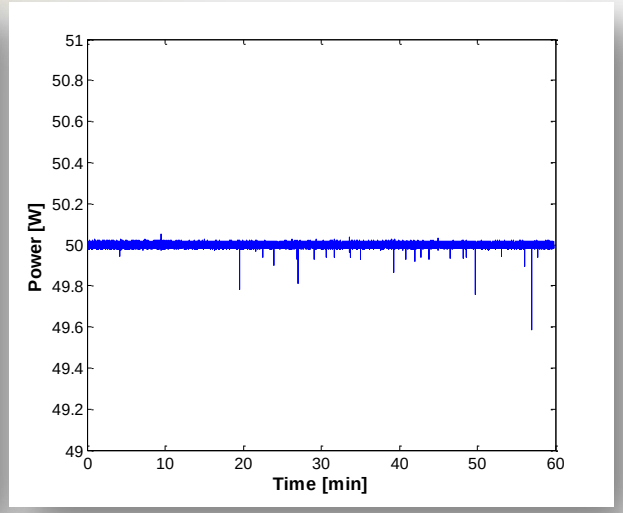
Data collected on NXE:3100 source in San Diego

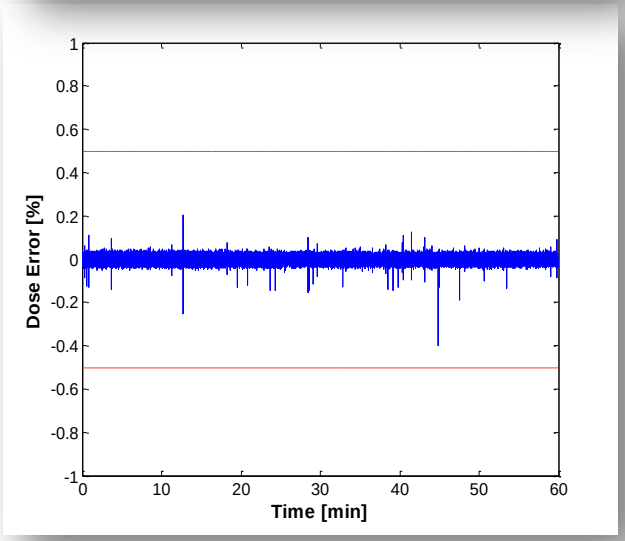
50W MOPA Prepulse EUV Power and Dose Stability

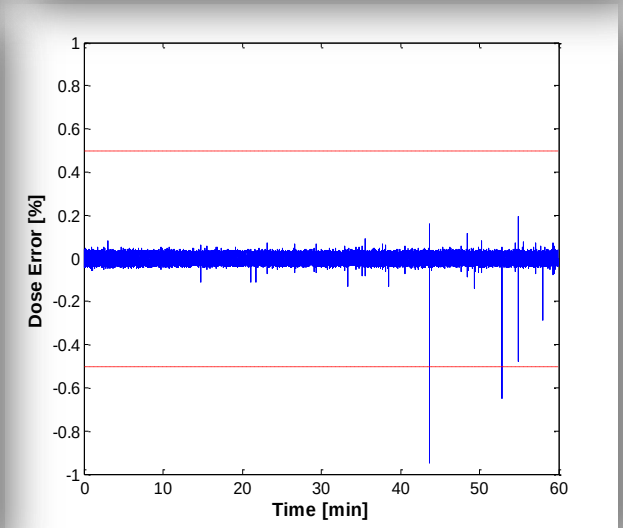
Dose Stability <±0.5%, Die Yield >99.7%

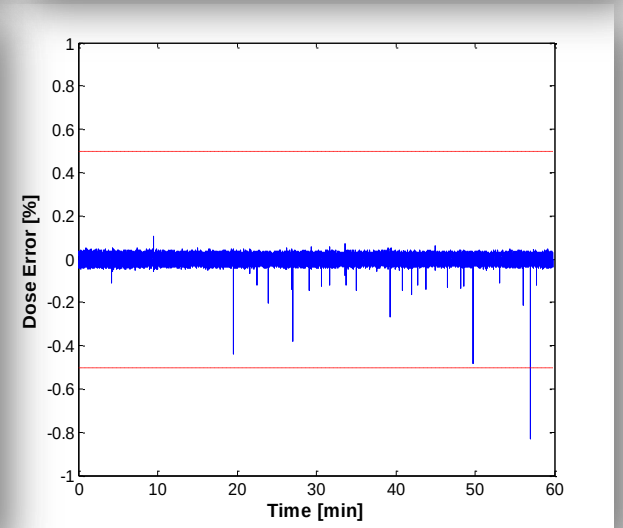






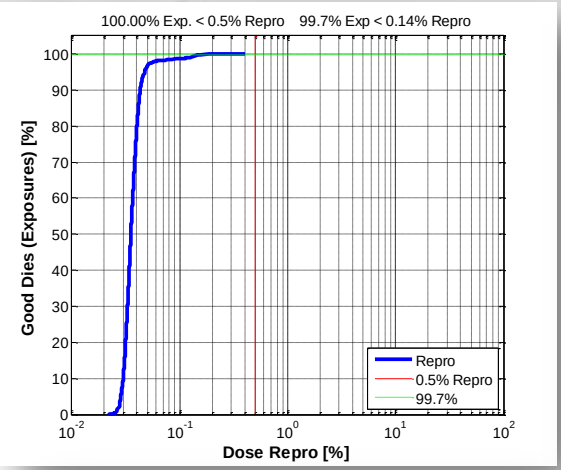


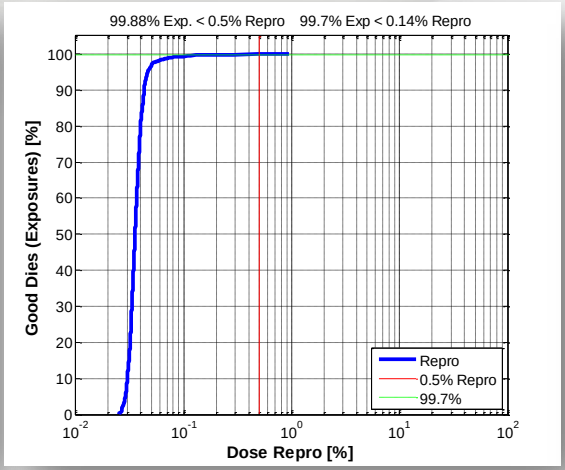


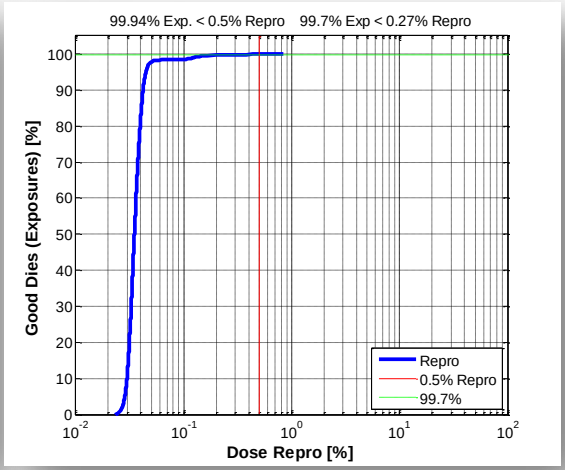


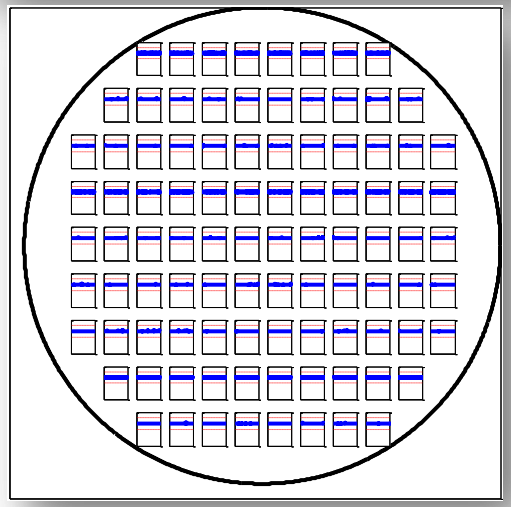
50W MOPA Prepulse Die Yield

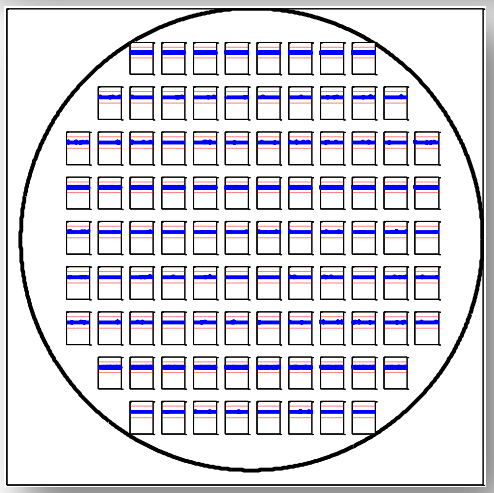
Die Yield Exceeds 99.7%, three runs of 1 hour each

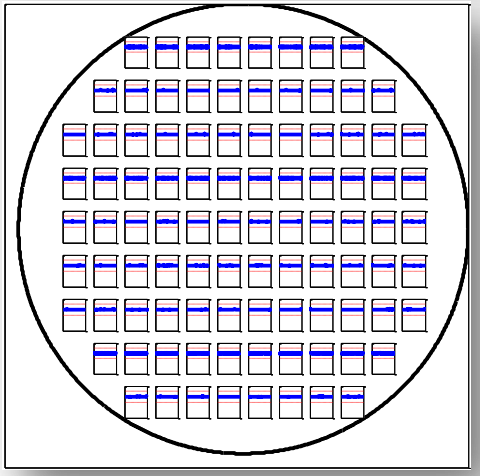








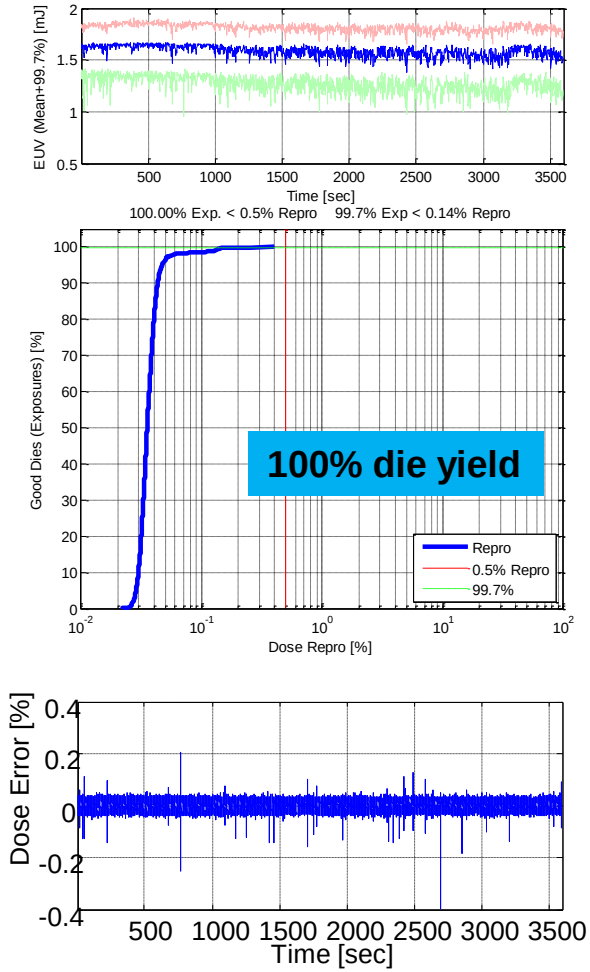




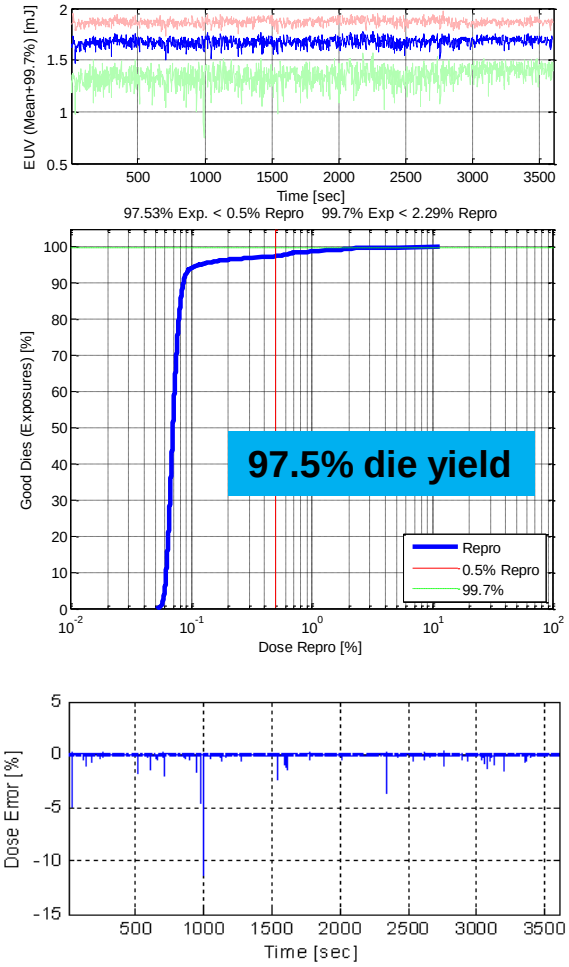
Data collected on NXE:3100 source in San Diego

MOPA Prepulse Power with Closed Loop Control up to 55W Demonstrated on P9 NXE:3100 at Cymer

50W

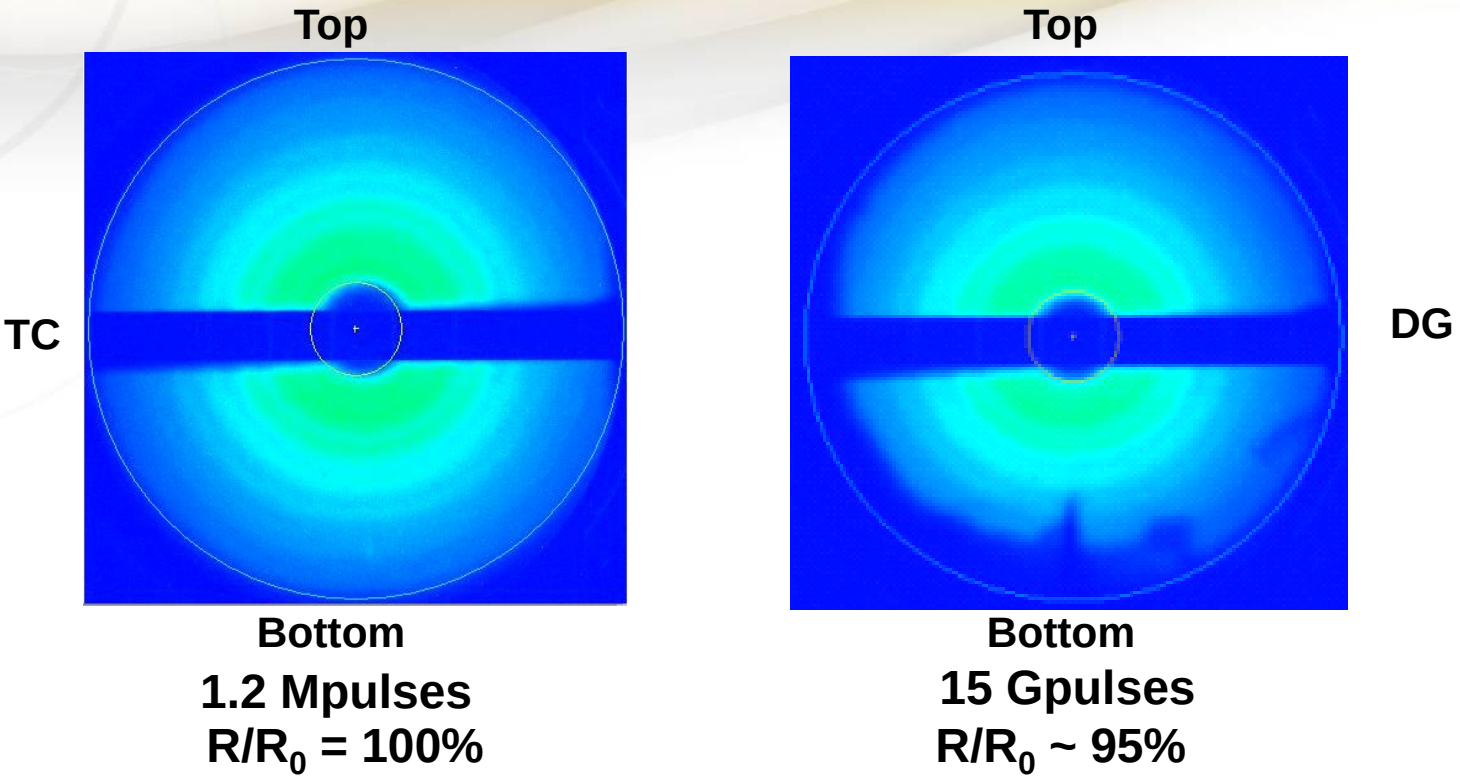


55W



MOPA Prepulse Collector Protection NXE:3100 Source

Collector Protection to 15 Billion Pulses Demonstrated



- **Operating conditions at 40W**
  - 50kHz Rep Rate
  - 2 sec die exposures, 100% DC within the burst, 92% burst to burst
  - Closed loop control in x, y, z, E and t

- **Collector Protection to 15 Gp without significant loss of reflectivity demonstrated**

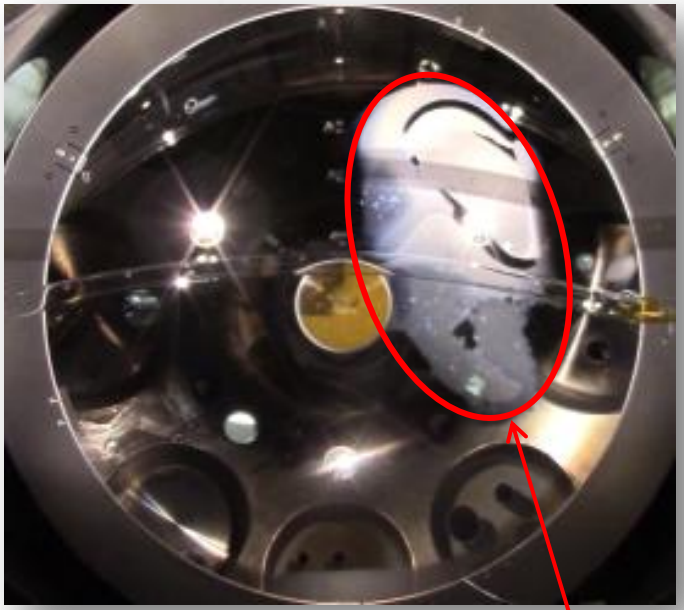
In-Situ Collector Cleaning

CYMER

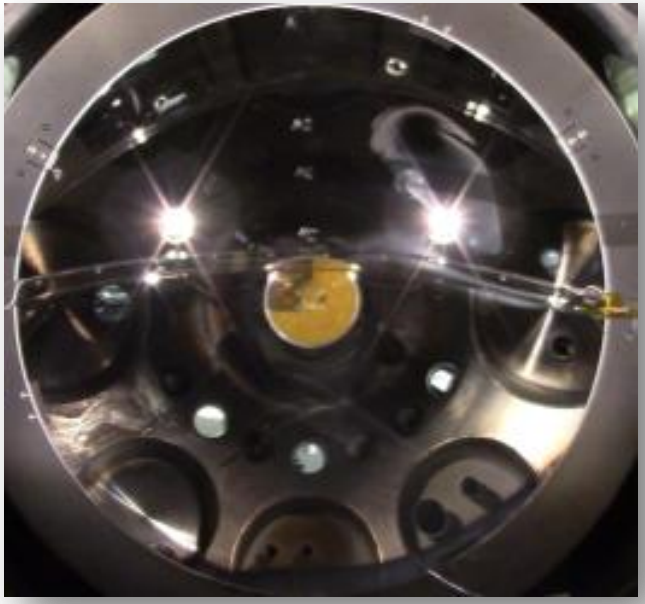
In-situ Collector Cleaning Demonstrated

Game changing technology for Uptime and COO

- **Cleaning on standard MLM capped NXE:3100 Collector**
  - Tin deposited during normal EUV operation was removed



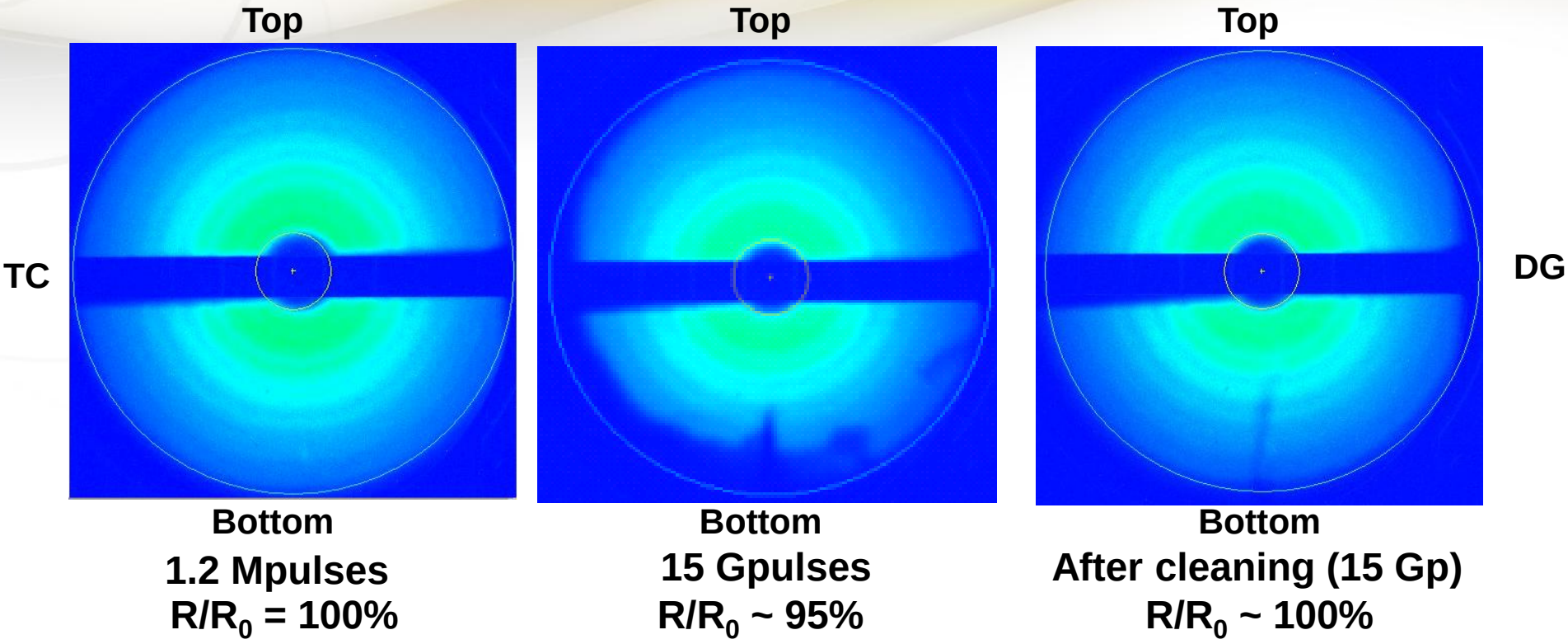
- **Start of test**



- **Collector after cleaning in-situ (in the vessel)**

MOPA Prepulse Collector Protection NXE:3100 Source

Collector Cleaned at 15 Billion Pulses



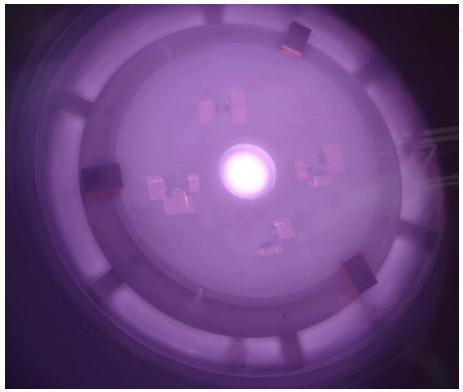
- **Operating conditions at 40W**
  - 50kHz Rep Rate
  - 2 sec die exposures, 100% DC within the burst, 92% burst to burst
  - Closed loop control in x, y, z, E and t

- **In-situ cleaning demonstrated recovery of original reflectivity**

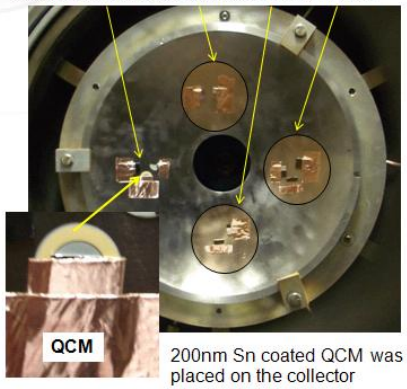
Collector Cleaning using RF Plasma

- Cymer funded project with University of Illinois at Urbana – Champaign
- Demonstrated 200nm Sn cleaning from Si sample placed on collector surface
- Demonstrated 25nm Sn cleaning from the entire 300mm dummy LT-1 collector

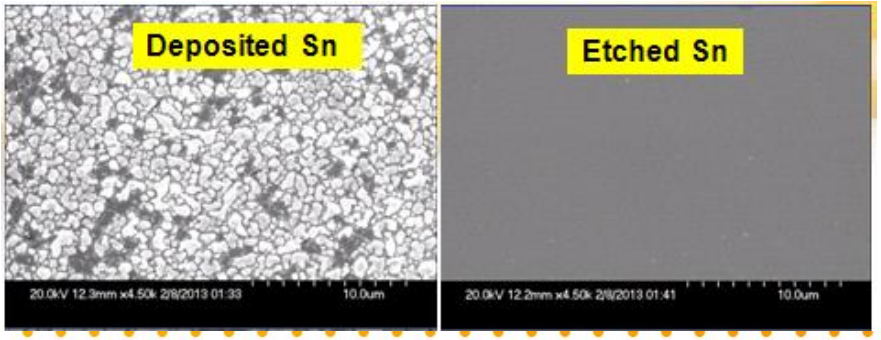
200nm Sn cleaning from Si samples placed on collector surface



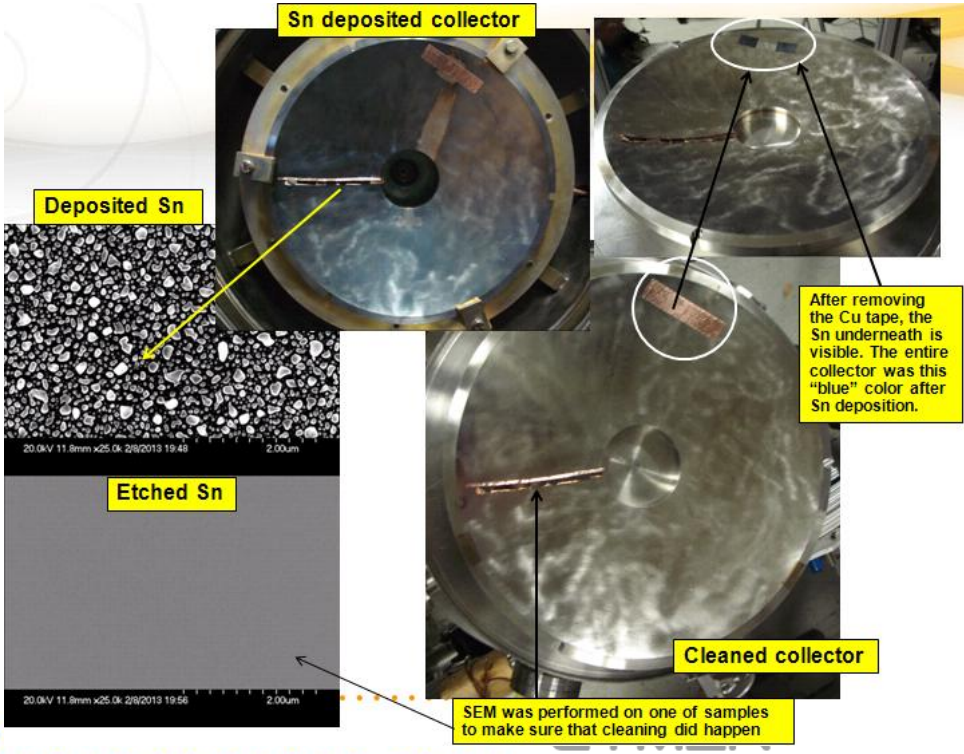
200nm Sn and 50nm Sn coated Si samples were installed at various locations on the collector



200nm Sn coated QCM was also placed on the collector



25nm Sn cleaning from 300mm dummy collector



Refer to Dan Elg's talk for more details

Power Scaling

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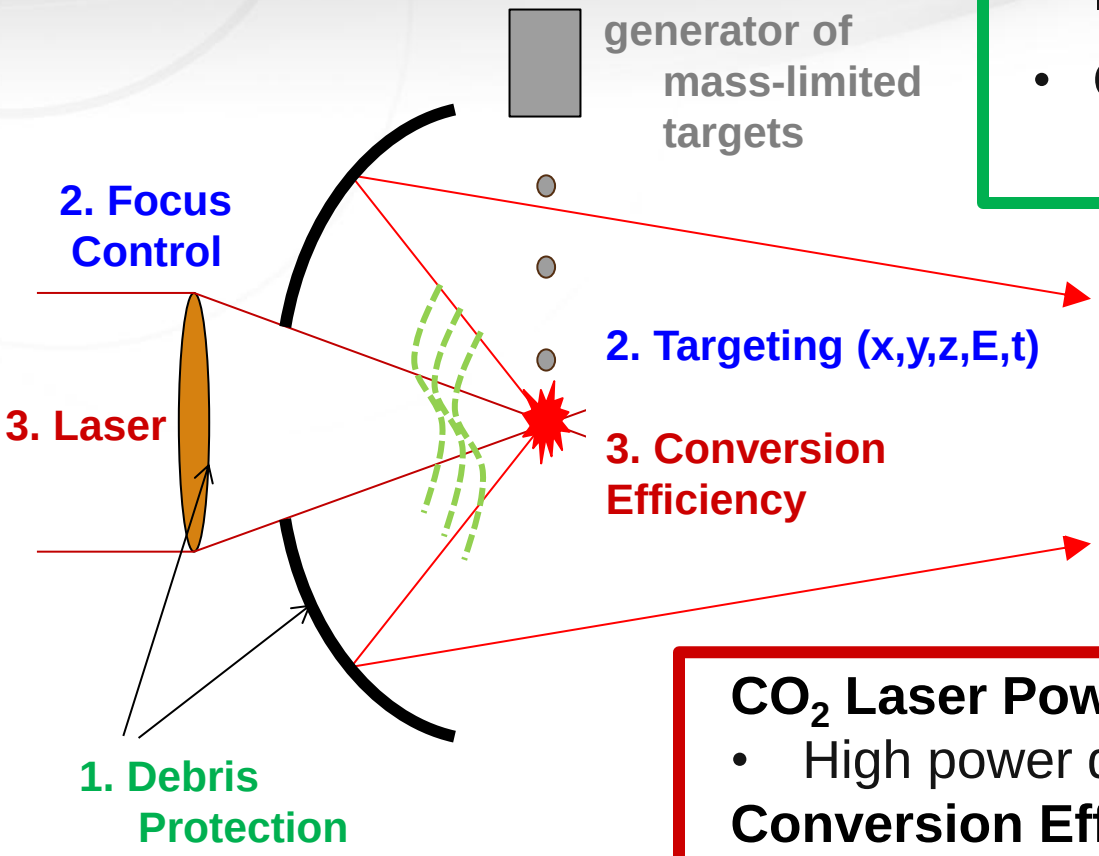
EUV Power Scaling
Top Technology Challenges



Optics Protection 1
(Debris Management)
- Collector protection by H_2
- In-situ collector cleaning
- Collector capping layers

Availability / CoO

Targeting Dynamics 2
- Target conditioning
- Focus Control
- x,y,z, E & t control

Dose Control / Yield

CO_2 Laser Power 3
- High power drive laser

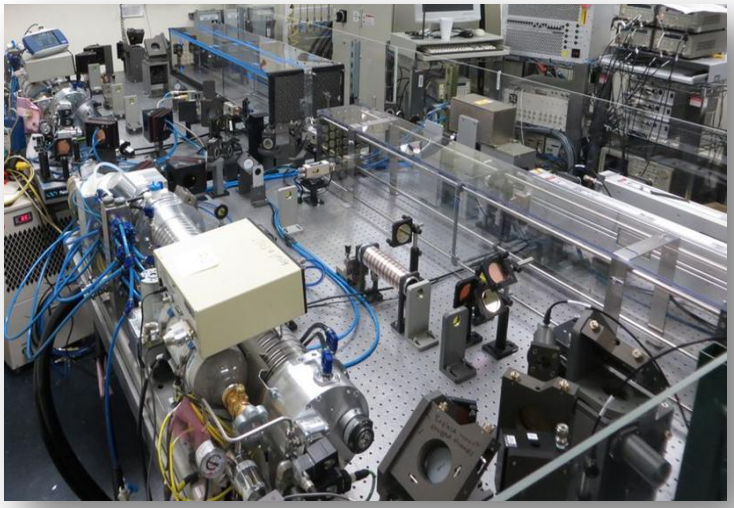
Conversion Efficiency
- Prepulse

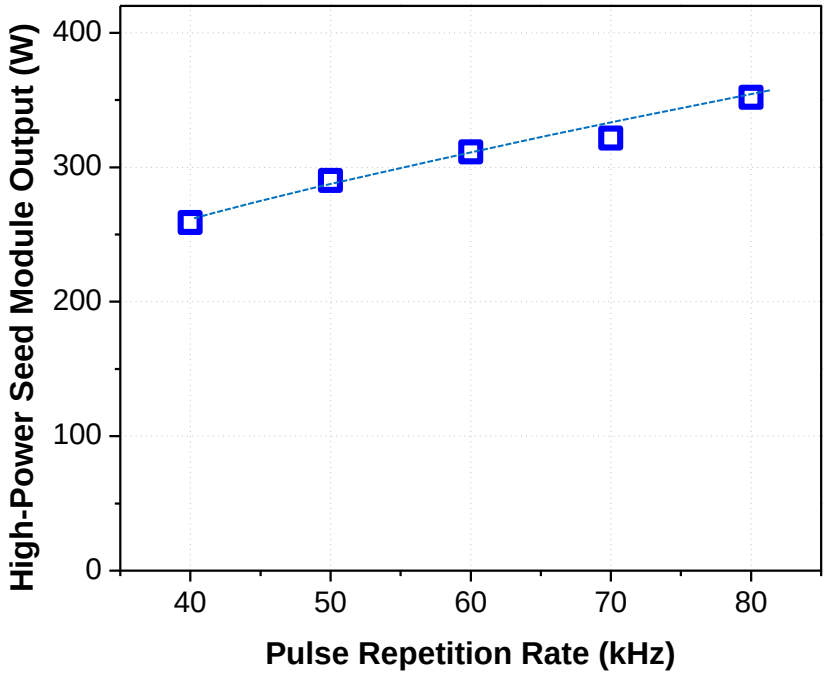
EUV Power / Throughput

High Power Seed Laser is Key to the Drive Laser

350W at 80kHz Demonstrated

- Seed Laser power delivery to the amplifiers is critical to achieving saturation and maximum power extraction from the amplifiers
- 350W target design power at 80 kHz repetition rate
  - Already achieved in system-level bench testing



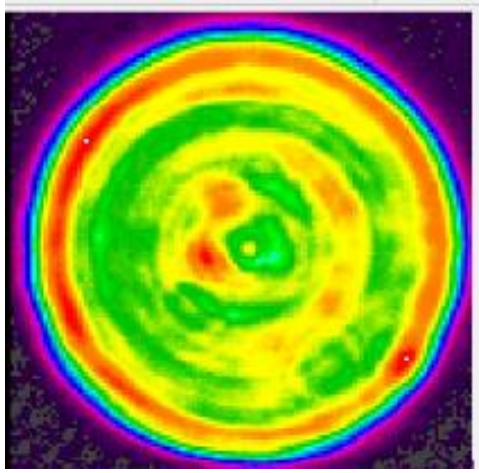


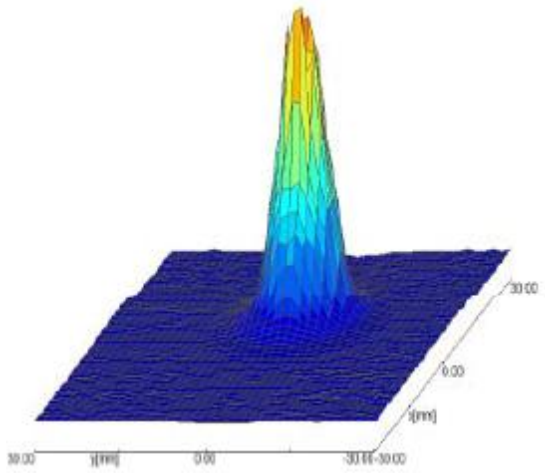
New Amplifier for Increase Power is Operational

Reached maximum of 35kW with good laser mode profile

- Higher power amplifier development completed at supplier
- Repeatable, stable operation up to 35kW (increased from 20kW)
  - Single amplifier continuous (cw) output power
- Good beam quality measured → good focusability

35kW cw

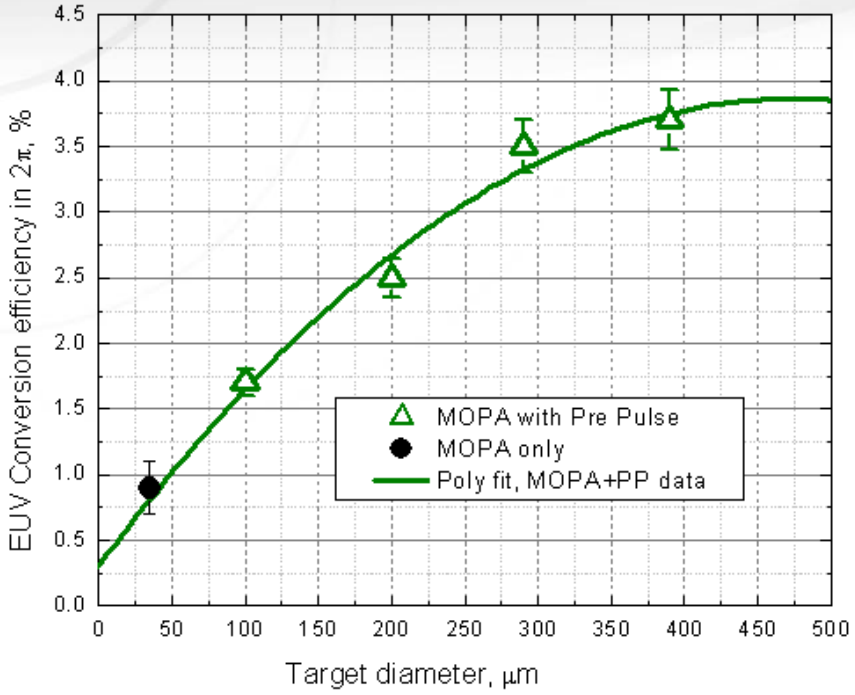


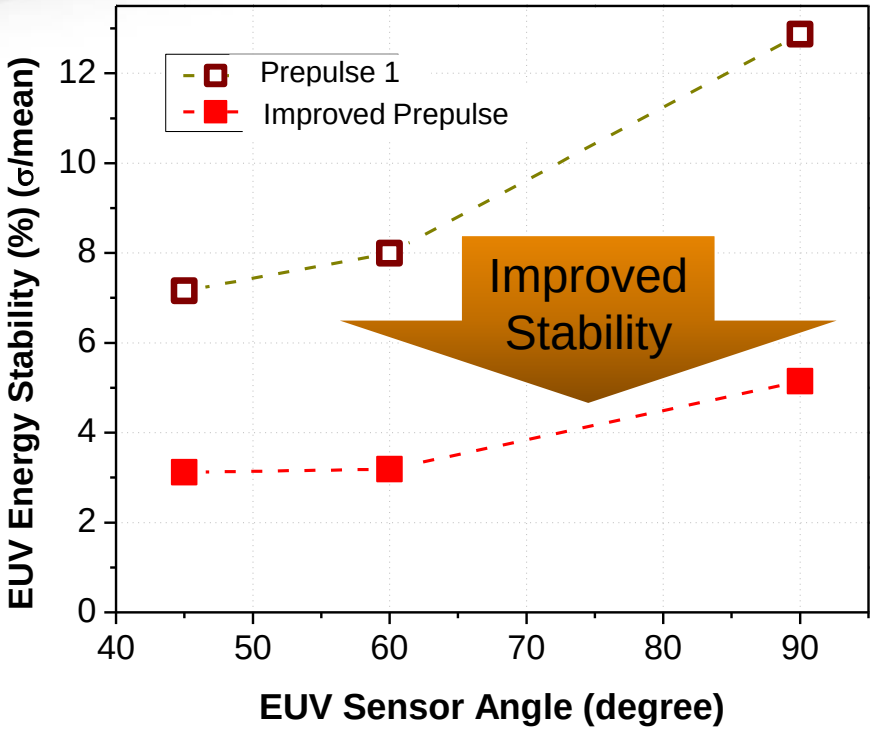


Good beam quality

MOPA Prepulse Technology for High Power Sources

Improved Prepulse shows 3.7% CE, driven by target size and stability (droplet and expanded target)





LT1 EUV power at low DC

720W in 2π → **176W raw at IF** → **140W at IF**

(calc dose controlled)

Roadmap and Summary

CYMER

EUV Source Power Roadmap

Power Scaling with Increased CO_2 Laser Power and Conversion Efficiency

	NXE:3100	NXE:3300B	NXE:3300B	NXE:3300B
EUV dose controlled power (in-burst)	50W	80W	125W	250W
Drive Laser	15kW	26kW	33kW	47kW
CE	>2%	3.0%	3.0%	3.3%

NXE:3100 Vessel


NXE:3300B Drive Laser


NXE:3300B Vessel

NXE:3100 Sources: Now in global field support phase

NXE:3300B Sources: Deliveries to Chipmakers in process

Summary

- Five NXE:3100 sources operating in the field for >2.5 years → 40,000 wafers cycled through R&D organizations
- Multiple NXE:3100 sources operational in MOPA Prepulse for early learning and technology transfer to NXE:3300B program
- Multiple NXE:3300B sources operational in MOPA Prepulse in San Diego and Veldhoven for system qualification
- 50W source power with exceptional dose stability demonstrated on multiple test runs over many days of operation
- Collector protection demonstrated over 15 billion pulses in MOPA Prepulse mode of operation
- In-situ collector cleaning capability demonstrated to increase uptime and reduce COO

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Thank you!

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Leading the Light Generation.

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